THE CONSTANT-ELEVATION FREE-BALLOON FLIGHTS FROM FORT OMAHA.

By C. LEROY MEISINGER.

[Dated: Weather Bureau, Washington, Sept. 15, 1919.]

SYNOPSIS.—By means of two free-balloons from Fort Omaha, Nebr., sailing at constant elevations of 5,000 and 10,000 feet, respectively, it was possible to determine with fair accuracy the trajectory of an air particle in the given pressure distribution. The upper balloon was able to maintain its elevation much more satisfactorily than the lower, because of its comparative freedom from the effects of the Ozark Mountains. A comparison of the actual speeds of the balloons with the computed wind speed or gradient wind shows that the lower balloon, especially during the smoothness of the night, averaged within 0.5 meter per second of the computed speed. The paths of both balloons were practically the same, showing that the effect of the controlling cyclone, the center of which was over the Great Lakes, persisted to a considerable height. The speed of the upper balloon was slightly greater than that of the lower.

Purpose.—The idea which culminated in the free-balloon flights from Fort Omaha on April 16, 1919, came indirectly from W. J. Humphreys, professor of meteorology in the Weather Bureau. The following extract from a memorandum written by Mr. Willis Ray Gregg, meteorologist, Weather Bureau, will best explain the purpose and value of the enterprise:

* * * Although observations of temperature, etc., during a free-balloon flight would be interesting, their value is questionable because, of course, the balloon is moving with the wind and the instruments, therefore, receive but little ventilation. The following project would be well worth attempting:

Have the balloon reach and maintain a certain definite altitude, e. g., 2 kilometers above sea level, and drift with the wind for as long a period as possible. The observer should note carefully the places passed over, and make a report with a sketch of the route covered. This would enable us to determine the actual trajectory of a particle of air under the influence of a given pressure distribution. Shaw and Dines have done much theoretical work along this line and it would be extremely interesting and valuable to have data for checking their conclusions.

This suggestion is not original with me, it having been proposed recently by Prof. Humphreys during a conversation as to suitable lines along which the work of this division should be developed.

Thus, the purpose of the flights was to determine the trajectory of an air particle, acting under the influence of a given pressure distribution, with a view to checking theoretical considerations previously made.

Methods employed.—The plan, as worked out at Fort Omaha, consisted in sending out two free balloons of equal capacity—one to travel at an altitude of 5,000 feet and the other to maintain an altitude of 10,000 feet above sea level. Thus the purpose, as set forth above, would receive double consideration, and, in addition, would afford the advantage of simultaneous observations at different altitudes.

The story of the journey.—Before proceeding to the discussion of the meteorological aspects of the flights, I shall narrate briefly some of the experiences of the voyages. For convenience, the balloons were numbered 1 and 2, the lower being No. 1 and the higher No. 2. The lower balloon was manned by Lieut. Col. Jacob W. S. Wuest and Lieut. Ralph A. Reynolds; the higher, by Capt. Frank W. Goodale and myself. As to the experience of the lower balloon I will quote from an account written by Lieut. Reynolds:

"Our balloon was following the general course of the Missouri River and was slowly climbing to our prearranged altitude. The junction of the Platte and the Missouri was below us, and Plattsmouth was just ahead. We soon passed Nebraska City and Auburn, * * * and at 3:30 a. m. we were crossing the Kansas River at Lawrence. At 6:30 we crossed from Kansas into Missouri, and five minutes later the sun appeared on the horizon, beamingly confident that we would soon rise to a higher altitude. The green fields stretched away as far as the eye could see like a vast checkerboard. The mining region around Joplin and Carthage was visible, and one could make out the dim outlines of the foothills of the Ozark Mountains. Below us were lilac bushes in purple bloom and cherry trees proudly bore their white blossoms.

"Our trouble was about to begin. The cooling effect of the woods began to contract our gas and we began to drop.[1] Ballast was thrown and we ascended slowly until we reached a height where the mountain winds failed to affect the balloon, then the sun expanded the gas until we ascended far above our desired altitude. We valved down to this altitude and the mountain winds greeted us again. This process was repeated with varying success several times. Finally the ground wind became so strong that, as we would come down near the tops of the mountains, the cross currents would assume control of our balloon and take us wherever their slightest whims would dictate. This was not the most soothing thing for our nerves at this particular time; also we were running short of ballast. It was decided to go high enough to get above the effect of the mountain currents and remain there until we had passed the vicinity of the Ozarks. We attained an altitude of 13,000 feet, where we remained until we had chosen our landing field. The balloon was valved down to 7,000 feet, where we were caught in a warm, vaporous cloud. This sent the balloon up to 10,000 feet again, which was highly disturbing since we had only five bags of ballast (about 150 pounds) left. However, we began our descent and came down at the rate of 900 feet per minute to 4,000 feet. At this point we poured over our water, which checked us slightly. But as we neared the ground, the radiation of heat from the ground checked us completely at 300 feet.

"We made an uneventful landing at Cabot, Ark., at 2:35 p. m. Before many minutes had elapsed, many of the natives of the section were on the scene and giving us every assistance possible. Their genuine hospitality was most charming and was one of the most pleasant incidents of the whole journey."

Thus it seems somewhat of a paradox to speak of this as a constant-elevation flight: nevertheless, this irregularity occurred in the latter part of the journey only, for the altitudes maintained during the night were quite constant.

I will tell in somewhat greater detail of the trip in the upper balloon. The first balloon was led from the balloon house at 10:35, followed by the spectators. After a very little weighing off, and with no confusion, it slipped off into the moonlight. The crowd now turned back into the balloon house to see the getaway of the second. Our balloon was not filled to capacity, because of the fact that we were to ascend to the higher altitude, and there would naturally be a loss of gas through expansion. If we had had the full 35,000 cubic feet, however, we could have gotten away with more ballast; as it was, the situation was "pitiful," as one onlooker described, for bag after bag of sand and one of the water bottles had to be sacrificed before the balloon manifested any desire to rise. Finally we were dispatched into the night at 10:45. It was indeed impressive to us in the basket to see the uplifted hands waving to us, and the uplifted faces, illumined by the pale moon, and to hear the good-by calls growing fainter as we receded.

[1] There may have been a down-current as well.—C. F. B.

In an hour, we had touched the 10,000-foot mark, and had been carried down the valley of the Missouri, first in Iowa and then in Nebraska, due to the devious course of the river, until we were 10 miles northeast of Nebraska City. We were now permitted to realize the beauties of a night trip at high altitude. True, it was cold—the thermometer had dropped to 8° F.—but the beauty of the moonlit landscape, studded with cities, more than offset any trifling physical discomfort. First, of course, there was Omaha, with Council Bluffs across the river. The streets, the cars, the automobile lights, the blinking electric signs—each was doing its dazzling bit. As we withdrew from the city, we saw villages on every hand, some with only two or three street lights, but others more generously illuminated. So high were we that the lights of Lincoln, hazy in the horizon mist, could be discerned. Later, we passed near St. Joseph and Kansas City, which vied with Omaha in scintillating beauty. Above, the sky was clear, save for a few wisps of cirrus; the white moon rode in triumphant splendor, and a meteor slipped silently, fading in a vaporous mist.

About 5:30 the dawn began and the countryside seemed to change in character completely. The lights of towns began to fade, the colors of the fields began to assert themselves—where there had been shades in the moonlight, there now were tints. At 7 o'clock we crossed out of Missouri into Arkansas in a southeasterly direction.

Perhaps through sympathy with the proverbially slow train, the wind speed was noticeably less and we began to drift lazily along. The rising sun began to expand our gas and we showed a tendency to rise, although the effect was not too strong. After the altitude of 12,000 feet was attained, we valved back to 10,000. The Arkansas River was plainly seen to the southwest, while far in the southeast, in the glint of the morning sun, were seen bright spots in the haze, which were unmistakably bends in the Mississippi near Memphis.

As to exactly what we saw, I shall not attempt a description. The Ozarks are beautiful, the winding white roads threading themselves about the hills served to lead the eye from one hamlet to another, while the railroads pursued sweeping curves over trestles and through tunnels. The hills themselves were chiefly evident by the shadows they cast. Passing out of the mountains, we came in sight of Little Rock—near enough that we could see the white statehouse, and the bridges over the Arkansas River.

By this time we were getting over the Arkansas Valley east of Little Rock. The country seemed to be very swampy, and where the ground was bare it was apparently wet,—but where the pine forests spread along for miles we could see the water shining and reflecting the skylight among the trees. Over this forest area and swamp land a tendency to descend required an almost constant expenditure of ballast, of which we had none too much. We seemed to be drifting slower and slower, and now that we were approaching the Mississippi were aware that we were being pulled toward it. As far as the eye could reach, the serpentine Mississippi continued its amblings and more and more we seemed to come into its control.

Of all the hundreds of square miles within our view, there were only a very few which appeared to be cleared and under cultivation, and in which we might effect a landing. But, at this altitude, there was no other prospect than a wet landing in the river. In consequence, we threw some ballast and in a few minutes were sailing at 12,500 feet, and happily drifting across the river toward the east. We passed directly over the town of Greenville. On the river was a steamer, and to the right lay Greenville; a large cumulus cloud far below blotted out the town of Arkansas City. With so little ballast and so few available landing spots it was decided to land at once.

I must digress, for the moment, to mention the physiological and psychological effects of the long period at the high altitude. Capt. Goodale is not inherently belligerent, nor am I, but it did happen that for a time we entertained more or less hostile sentiments for one another. I do not mean that either of us sought to heave the other out of the basket, but we became mutually sullen for no cause at all. It was later explained by the physicians at the fort, as due to nothing less than the fatigue caused by a lack of the proper constituents in the atmosphere at that level. Indeed, we are informed that a small tube of oxygen would have acted as a literal elixir d'amour, and the captain and I can recommend its being carried as a great benefactor at high levels.

Our descent from the lofty altitude was quite rapid; for six minutes we fell at 1,000 feet per minute, which is decidedly too fast for comfort. Due to the rapidly changing barometric pressure, the desire is to hold one's mouth as widely open as possible to adjust the lungs to the new conditions. As we neared the ground we noted that the ground temperature was very high; moreover, the air was oppressively humid and stuffy. This warmth acting on the gas in the balloon served to expand it faster than it could escape through the valve, although the valve was held open continuously. Thus we dragged across the first field, unable to get down. We were approaching a railroad track with telegraph lines and trees beside it. These had to be jumped; consequently our attention was turned to getting ballast over. Our lunch was the nearest thing at hand, and there ensued a veritable rain of boiled eggs, oranges, and chicken sandwiches upon the plantation below. But they served their purpose, for we jumped the wires.

We were able to get down in the next field after having the bag, in deflating, parachute sidewise in the netting and drag us through muddy pools for about a quarter of a mile with the basket on its side. We were on a cotton plantation near Arcola, Miss., and of course were surrounded by a crowd of negroes, who were of the opinion that we had fallen unintentionally. They had been watching us, they said, for about an hour, and were quite amazed that we should precipitate ourselves voluntarily in their midst.

Now, the effect of the high altitude and our rapid descent asserted itself. The captain, to whom packing a balloon is almost a subconscious operation, went through the work in whirlwind fashion, while I was so mentally befogged that I had to think twice how to do the most ridiculously simple things. An overwhelmimg desire to sleep overcame me. As soon as the packing up was concluded, the captain complained of a splitting headache, and I could have toppled over in the mud for the sake of a little rest.

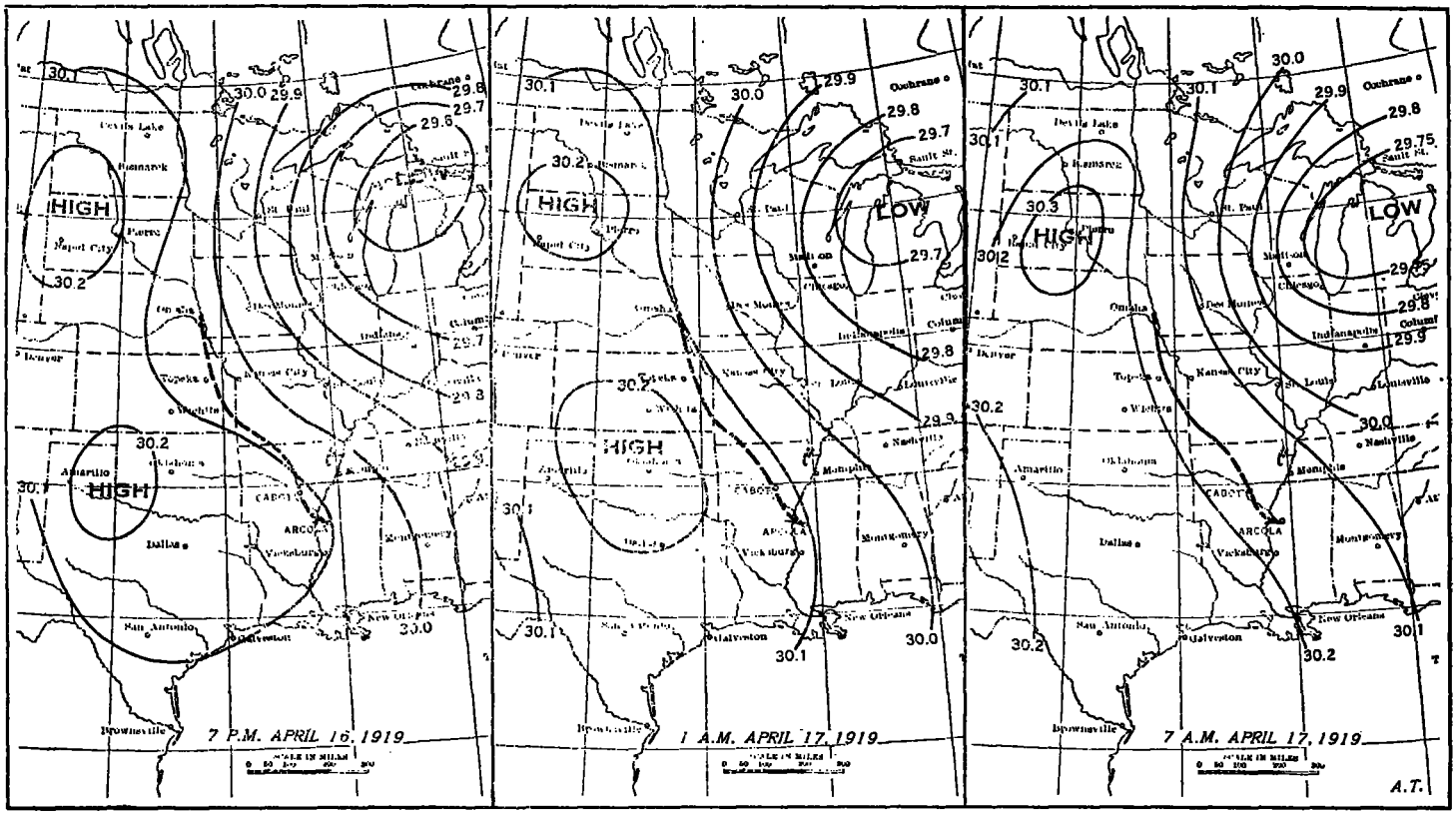
These are the salient features of the trip from a popular standpoint. It will now be of interest to discuss the trip from a more scientific standpoint.

Pressure distribution.—Figures 1a, 1b, and 1c represent sea-level pressures at 7 p. m., April 16; 1 a. m., and 7 a. m., April 17, 1919. Figure 1b is drawn for 1 a. m., April 17, and is interpolated from the maps of the pre-

ceding evening (1a) and the following morning (1c). The trend of the isobars is, in general, the same in all three maps.

On each of these charts is shown the path of the balloons. The solid part of the line indicates the portion traversed up to the time of the map, the dotted part shows the route taken after the time of the map.

Figure 2 is almost self-explanatory, since it represents the courses of the two balloons, as seen laterally. The topography is represented in solid black in cross section along the path. The cities and towns passed over are also indicated. The abscissae represent miles traveled, and the ordinates represent altitudes in feet. The hourly positions of the balloons in their paths are indicated.



FIGS. 1A, 1B, 1C.—Pressure distribution during the flights.

At Fort Omaha, all day previous to the flights, there was a steady NNW. wind. It was cloudy all day with a tendency to break up toward evening. It had been contemplated at first to start the flight about 6 p. m., but at that time the sky was still overcast, so that it was at once obvious and necessary that the flights be postponed, since a clear sky was imperative to the successful accomplishment of our purpose. There was a very rapid clearing at 9 p. m., which assured the trip, and at 10:33 and 10:45 p. m., respectively, the balloons took to the air.

It is seen from this chart that the first portion of the flights is most valuable for the purpose, since better equilibrium was obtained before the influence of the sun was felt. Another interesting fact is that both balloons followed practically the same course, the slight deviations of the lower one being due, without doubt, wholly to the effect of the currents about the Ozark Mountains, which were not experienced by the upper balloon. This emphasizes the point that the winds on the western or southwestern portion of a LOW seem to persist to great heights

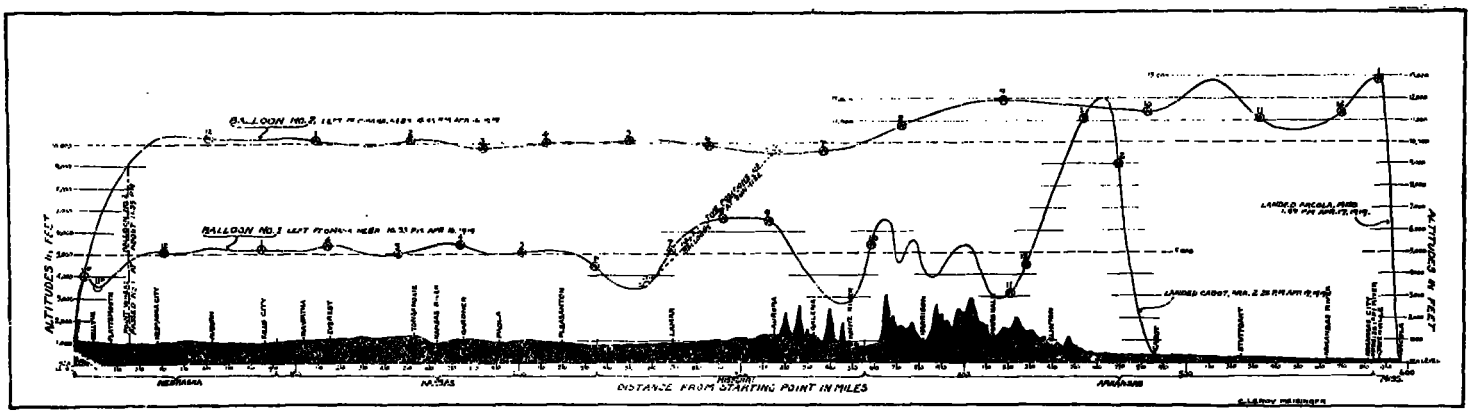


FIG. 2.—Lateral projection of balloon flights.

Gradient winds.—It is of interest to compare the actual directions and speed of the balloons with the theoretical "gradient wind," which is defined as the wind in which equilibrium is maintained between the pull of gravity down the pressure slope, the deflective tendency due to the earth's rotation, and centrifugal tendency due to the curvature of the wind path. The direction of the gradient wind is normal to the pressure gradient or parallel to the isobars. The effect of friction becomes so small at a height of only a few hundred meters that the actual wind above such heights is essentially the same as the gradient wind.

TABLE 1.—*Speeds and altitudes.*[1]

(See Fig. 3.)

Time.	Gradient velocity.	Balloon No. 1. (5,000 feet= 1,524 m.).		Balloon No. 2. (10,000 feet= 3,048 m.).	
		Speed.	Average altitude.	Speed.	Average altitude.
p. m.	*Meters/sec.*	*Meters/sec.*	*Meters.*	*Meters/sec.*	*Meters.*
11 to 12		13.4	1,371	23.2	2,591
a. m.					
12 to 1		19.7	1,554	21.5	3,048
1 to 2	14.8 (?)	13.4	1,580	19.2	3,048
2 to 3		14.3	1,570	14.8	3,048
3 to 4		12.5	1,585	12.5	3,017
4 to 5		12.5	1,575	17.0	3,050
5 to 6		14.3	1,493	17.0	3,050
6 to 7		15.2	1,220	22.8	2,895
7 to 8		10.3	1,828	16.1	3,078
8 to 9	11.5	8.9	2,073	21.0	3,505
9 to 10		20.6	1,371	29.3	3,566
10 to 11		26.8	1,402	22.4	3,658
11 to 12		3.6	1,158	17.0	3,353
p. m.					
12 to 1		11.6	2,438	8.0	3,353
1 to 2		6.7	3,353		

[1] The English units which were used in the early portions of this paper were the units in which the data were actually obtained—from barographs, thermometers, etc. However, in the discussion of the data, it is more convenient to employ the metric units, and these have been used in the table and in the following discussion.

Table 1 and figure 3 show the distances actually covered by each balloon, taken from figure 2, and the average altitude during each hour. The computed gradient wind is shown in the second column. It is computed from the isobars at 1 a. m. and 7 a. m.

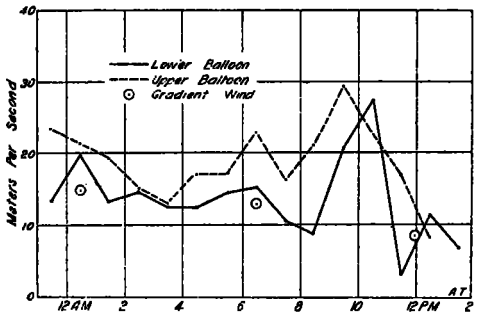


FIG. 3.—Speeds of the balloons.

It will be noted that the agreement during the night between the computed and the observed wind speed at the lower level is quite good. The average speed between 11 p. m. and 5 a. m. is 14.3 meters per second for the lower balloon, within 0.5 meters per second of the computed speed from the 1 a. m. map.

As was pointed out above, the altitudes, and the speeds at various altitudes, were so variable during the later hours of the trip that very little can be done by way of comparison. The computed winds given in the table are for latitudes 40° and 37° 30′, respectively.

It is obvious that the data obtained in a single attempt of this kind are too meager to be the foundation of any theoretical work. Nevertheless, a large number of such observations, where an attempt to maintain a constant elevation is strictly adhered to, would certainly contribute to our knowledge of the motion of air about centers of high and low pressure.

THE PHYSIOLOGY OF THE AVIATOR.[1]

By PROF. YANDELL HENDERSON.

(Abstracted from *Science*, May 9, 1919, pp. 432-441.)

The advantage which accrues to the aviator who is higher than his opponent has led to considerable flying at great altitudes. "Near the end of the war it was quite common for battle planes to ascend to altitudes of 15,000 to 18,000 feet. * * * Along with this development there occurred with increasing frequency among the aviators a condition closely similar to, perhaps identical with, the 'overtraining' or staleness, the physical and nervous impairment of athletes in a football team or college crew." Both conditions seem to be the result of frequently recurring short periods when the body has insufficient oxygen.

"Paul Bert,[2] the brilliant French physiologist, was the first to demonstrate, in 1878, that the effects of lowered barometric pressure or altitude are wholly dependent on the decreased pressure of oxygen."

Thus, these effects are different from those of caisson disease, which results from the formation of bubbles of nitrogen absorbed in the blood and tissues under high pressure, when "the pressure with which the tissues are in equilibrium should have been lowered considerably more than half its absolute amount in a few seconds."[3] Obviously, the aviator can not rise fast enough for this to occur. When the pressure is reduced the dissolved nitrogen diffuses rapidly into the air, and so the internal gas pressure becomes quickly adjusted to the external. "Nevertheless, the idea is still prevalent that hemorrhages occur in low barometric pressures. However, among thousands of people whom I had an opportunity to observe on Pikes Peak during a five weeks stay on the summit, I saw not a single nosebleed." * * * With oxygen breathing apparatus, two experimenters, "Schneider and Whitney, went into the steel chamber (at Mineola) and the air was pumped out of it until the barometer stood at only 180 mm., 23 per cent of the pressure outside—the equivalent of an altitude of 35,000 feet."

"To sum up all that has been said thus far, the influence of low barometric pressure is not mechanical but chemical. Life is often compared to a flame; but there are marked differences, depending upon the peculiar affinity of the blood for oxygen. A man may breathe quite comfortably in an atmosphere in which a candle is extinguished. The candle will burn with only slightly diminished brightness at an altitude at which a man collapses. The candle is affected by the proportions of oxygen and nitrogen. The living organism depends solely upon the absolute amount of oxygen—its so-called partial pressure."

[1] Presented before Harvey Society, Mar. 22, 1919.
[2] "*La Pression Barometrique.*" Paris, 1878.
[3] Further details are given by Prof. Henderson and still more by J. S. Haldane, Nature, Vol. 96, pp. 173-174.—C. F. B.